Guest Editorial

Nanogold – new opportunities for product development

Gold has long been a cornerstone precious metal occupying a premier position in the world economy, representing wealth and high value. Traditionally it has been used in its yellow lustrous bulk metallic form for monetary and jewellery applications and over recent decades as an electrical conductor and contact material in the electronics industry. In these applications, the chemical inertness and resistance to oxidation of the gold surface are important.

The exciting world of nanoscience offers new opportunities for gold through the emergence of optical and chemical properties which are different from those of the bulk metal. For example, when the particle size of gold is reduced to nano-sized dimensions, its conventional metallic colour is no longer observed. Instead, nano-size gold exhibits a variety of brilliant hues with the colour being dependent upon both the size and shape of the gold particles due to the phenomena of surface plasmon resonance. This is the coherent oscillation of conduction band electrons on the gold surface by the resonance interaction of the electromagnetic field of visible light. The theoretical basis for surface plasmon resonance scattering was developed by the German physicist Gustav Mie in 1908, who solved Maxwell's equations for the absorption and scattering of electromagnetic radiation by very small metallic particles, i.e. nanoparticles.

Interestingly in this regard, the world of nanoscience is not solely the domain of the 20th and 21st century as we often think. The remarkable dichroic optical effects observed in the Lycurgus Cup which dates back to Roman times in the 4th century AD, are in fact due to the interaction of light with metallic nanoparticles*. The cup is one of the most outstanding achievements in ancient glass craft and is an early example of combining a nanomaterial with a conventional substrate. The open framework decoration on the outside of the glass cup itself, depicts the triumph of Dionysus over Lycurgus. The glass of the cup appears red when viewed in transmitted light and green when viewed in reflected light. The effect is due to a colloidal dispersion of nanoparticles about 50-100 nm in diameter of a gold-silver alloy with minor copper, dispersed in the glass matrix. Much later, Michael Faraday recognised that the ruby colour in stained glass windows in cathedrals was due to a similar colloidal dispersion of gold particles, but at that time was not able to provide a scientific rationale for it. This was later developed by Mie. Gold colloids with spherical particles of about 7-20 nm particles appear as a deep red wine colour, which progressively changes through to a blue-grey colour with increasing particle size up to about 80-100 nm. Gold is resistant to oxidation and generally to chemical attack and hence the surface of the nanoparticles is stable in the environment. The colours are stable towards UV light and do not change, providing there is no change in particle size through the growth of discrete nanoparticles or agglomeration.

We have recently captured an exciting and proprietary opportunity to use gold nanoparticles as stable colourfast colourants in textiles and fashion apparel, in particular for the high quality fine fibres of merino wool and silk in fashion apparel and the coarser crossbred wool fibres in textiles and carpets. Hence the traditional high value and wealth associated with gold is innovatively transferred to high quality wool and silk substrates, thereby offering the textiles, apparel and fashion industries with a new and unique product suite based on nanotechnology, which is ideally suited to high quality couture. The resulting materials comprise only wool and gold, therefore the process has the desirable

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hallmarks of high quality and environmental attractiveness.

The success of this application as with other applications of gold nanoparticles such as in the catalysis, biomedical and sensing areas, requires a fundamental understanding of the chemistry relating to the nucleation, growth and stability of these nanoparticles, their surfaces and the way they are dispersed in and interact with the different substrates. In this case the substrate is a natural material which on a molecular and nanoscale, is highly variable and poses new and complex challenges that are generally not present when the substrate chemistry and the nanoparticle interactions can be carefully controlled. In addition, the textile and apparel industry is many centuries old and the introduction of nanomaterial colourants with a chemistry that is significantly different from traditional dyes, essentially means that new ideas and technology must be implemented and new investment required. This is often the case in other application areas and if the required changes are perceived to be too new or risky, the new development may not proceed. However on the market-pull side, the added value of using nanogold to provide new functionality to existing substrates or chemical processes is significant and enables the product to be differentiated more clearly and in a superior way. Hence the identification of a key competitive advantage emerges as the driving force and the impetus to capture the innovation can be very strong. The successful development of innovative new products which utilise nanogold therefore equally depend on achieving success in the developmental science as well as in the market place. Science innovation and market innovation must be synergistic and a high level collective awareness from the science and business sides is a necessary prerequisite for success. The science and applications of nanogold that will be presented at the forthcoming Gold2009 conference in Heidelberg offer a fertile ground for communicating new science innovations utilising nanomaterials and nanotechnology to industry, and hence for identifying new market and new business development opportunities.

**See article by I Freestone et al, GB 40 (4), 270-277.*